J. New York Entomol. Soc. 97(1):1–10, 1989

THE BIOLOGY OF *STHENOPIS AURATUS* (GROTE) (LEPIDOPTERA: HEPIALIDAE)

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Abstract.—Larvae of *Sthenopis auratus* (Grote) were found tunneling in the artichoke-like leaf bases and stems of several ferns: Ostrich Fern (*Matteuccia struthiopteris* (Linnaeus) Todaro), Marginal Shield Fern (*Dryopteris marginalis* (Linnaeus) Gray), Mountain Wood Fern (*Dryopteris campyloptera* (Kunze) Clarkson), and Lady Fern (*Athyrium filix-femina* (Linnaeus) Roth), all Polypodiaceae. An ichneumonid parasite, *Pterocormus devinctor* Say, was associated with a cocoon of *S. auratus*. The early evening calling behavior by males is described. The male has prominent androconia on the hind tibia presumably for dissemination of a pheromone. Males did not seek out females, but rather adopted sessile calling displays on emergent understory vegetation. Additional locality records are given for this rare northeastern moth. The larva and pupa are described and illustrated in detail.

Sthenopis auratus (Grote) (1878) is among the rarest of hepialids in North America (Winn, 1909; Beutenmüller, 1913; Forbes, 1923). Its biology was heretofore completely unknown. Few moths are represented in collections. *S. auratus* has been reported from St. Johns and Brome County, Quebec; Black Mountains, North Carolina; Franconia Mountains, New Hampshire; and in New York in Lewis County and at Fentons, Lancaster, Ithaca, McLean, and in the Catskills (Beutenmüller, 1913; Forbes, 1923).

New locality records for New York include Rensselaer (Mill Creek, Rensselaer County) (TLM, Quinter, Dievendorf), Cambridge and Murray Hollow (both Washington County) (Romack, TLM, DLW), Whiteface Mountain (Essex County) (TLM), Indian Lake (Beaver Meadow, Hamilton County) (TLM), Rensselaerville (the Huyck Preserve) (TLM, Quinter, Franclemont) and Albany (Pine Bush) (both Albany County) (TLM). In Vermont, it has been recorded from Camels Hump (Chittenden County) (Don Tobi).

Larvae of *S. auratus* were recovered most frequently from Ostrich Fern, *Matteuccia struthiopteris* (Linnaeus) Todaro. Aderkas and Peterson (1987) provided a partial list of insects associated with Ostrich Fern, but did not report the hepialid, perhaps because their research site was in Nova Scotia, a province for which the insect has yet to be recorded (Douglas Ferguson and Berry Wright, pers. comm.). Nonetheless, searching for larvae may be the most practical way to survey for the presence or absence of many hepialids, including *S. auratus*.

BIOLOGY OF *STHENOPIS AURATUS*

Larval hosts were identified as Ostrich Fern (*Matteuccia struthiopteris),* Marginal Shield Fern (*Dryopteris marginalis* L.), Mountain Wood Fern (*Dryopteris campylop-*

tera (Kunze) Clarkson), and Lady Fern (*Athyrium filix-femina* (L.) Roth), all Polypodiaceae. Ostrich Fern patches were observed to support the largest populations of the moth, perhaps because single rootstocks could support several larvae. As many as six larvae were recovered from a single rootstock of Ostrich Fern. Ostrich Fern did not appear to suffer from presence of larvae. No more than one larva was associated with a given individual of the other fern species. All four fern species shared a similar artichoke-like rootstock, with imbricated subterranean leaf bases.

The rootstocks of many Royal Fern (*Osmunda regalis* L.), Interrupted Fern (*Osmunda claytoniana* L.), and Bracken Fern (*Pteridium aguilinum* (L.) Kuhn) were searched for larvae without success. The size, form, and consistency of the root mass may be a limiting factor.

Early instar larvae were not observed. The majority of the larval collections were made in June 1987 at Murray Hollow. At this time, immatures representing two distinct cohorts were noted. The first consisted of middle instar to nearly fully developed larvae, which would not mature until summer 1988. The second cohort consisted of prepupal larvae and pupae, which would produce adults during the later part of June and early July 1987. This observation and our records for adult captures suggest that *S. auratus* has a two-year life cycle in New York.

In *Matteuccia,* larvae bored in the outer portions of the rootstock, tunneling into the leaf bases of previous years' growth. A single larva tunneled into several bases. In *Dryopteris* spp., the larval channel ran down the axis of the subterranean stem. In all ferns, the larval tunnel was relatively free of silk until the last larval instar when an elongate cocoon was spun in the tunnel. The elongate cocoon afforded the pupa considerable mobility. Prior to eclosion the pupa was thrust to the outside. Individual plants that are most likely to host larvae are the older, more mature plants with rootstocks that are most protuberant from the forest floor.

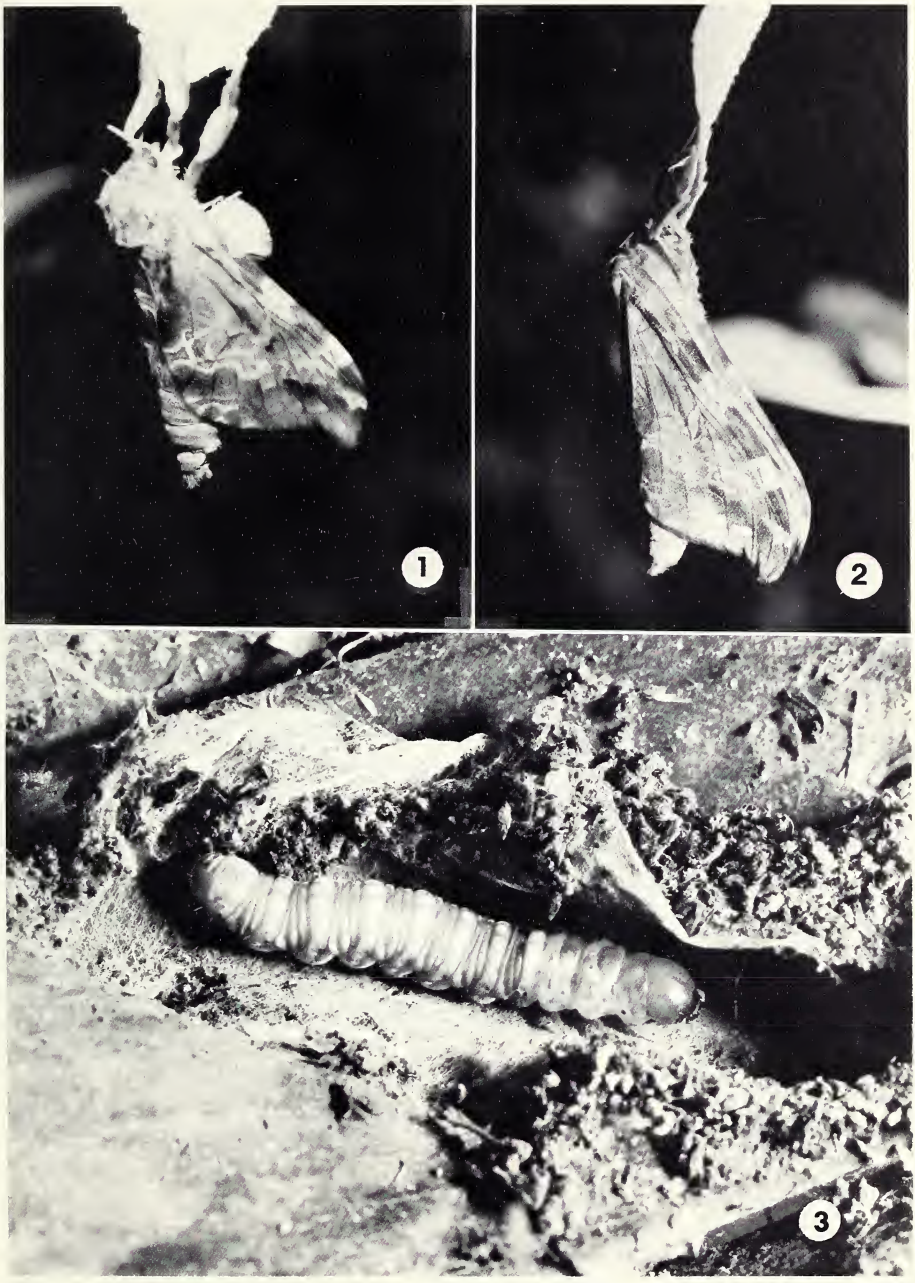
On June 12, 1987, both prepupal larvae and pupae were present in the Murray Hollow colony. Adults began flying at Murray Hollow in the later half of June, and no adults were taken after 15 July, which would suggest that the pupal stage lasts less than a month (Howard Romack, pers. comm.).

DESCRIPTION OF LAST INSTAR LARVA AND PUPA OF *STHENOPIS AURATUS* (GROTE)

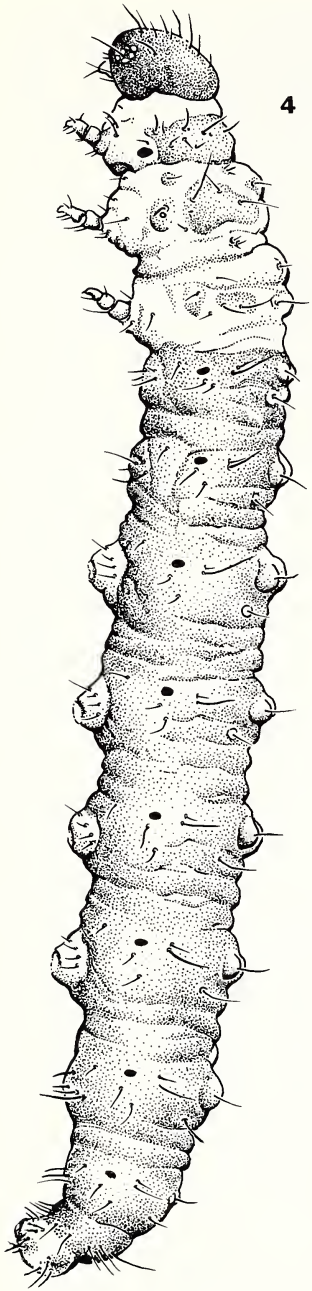
Larval characters for the Hepialidae have been given by Hinton (1946), Gerasimov (1937), Aitkenhead and Baker (1964), and Wagner (1987). We adopt Hinton's (1946) nomenclature for the larval chaetotaxy except for the D and SD setae on the prothoracic shield where Wagner (1987) is followed. We emphasize characters known or likely to vary among species or genera of Hepialidae. The pupal nomenclature follows Mosher (1916).

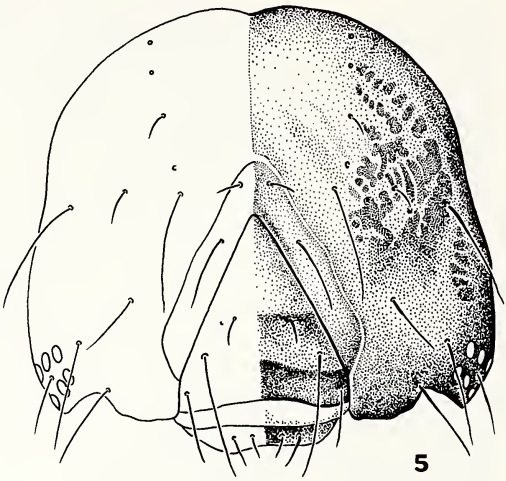
Late Instar Larva
Figs. 3–11

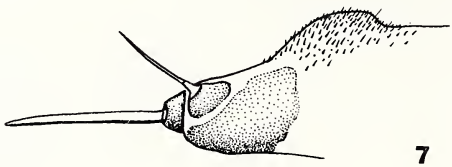
Length to 47 mm (preserved), N = 15. Head (Fig. 5) orange; width to 3.7 mm. Labrum shallowly emarginate to cleft, anterior half furrowed with 5 pairs of setae. Antennae as in Figure 11. Membranous frontoproximal portion of hypopharynx (Fig. 7) with sparse vestiture of spinules. Spinneret perpendicular to head, scarcely exceeding posterior margin of labium.



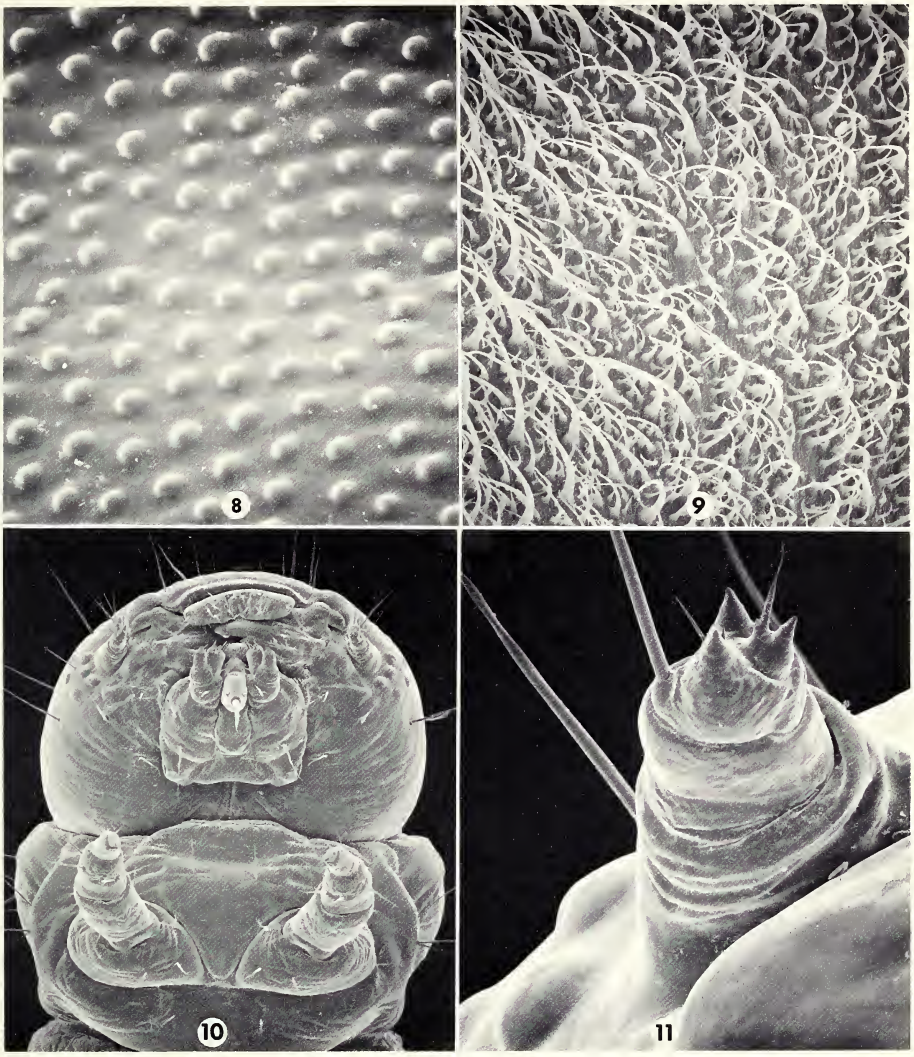
Figs. 1–3. *Sthenopis auratus*: 1. Male calling—metatibial scent brush visible just above middle of body; 2. Male at rest; 3. Mature larva shortly before pupation in rootstock of fern (notice silk-lined tunnel).







Figs. 4–7. *Sthenopis auratus* larva: 4. Habitus of mature larva; 5. Head capsule, frontal view; 6. Left mandible; 7. Hypopharyngeal complex.



Figs. 8–11. *Sthenopis auratus* larva: 8. Integument of thoracic segments which appears white (×1,000); 9. Microspinules of abdominal segments, which cause segments to appear rusty (×1,000); 10. Ventral surface of head and prothorax of larva (×25); 11. Antenna of larva (×250).

Thorax. Ground color white, setae on large, brown to yellow-brown, plate-like pinacula. Spinules reduced to platelets (Fig. 8). Prothorax with SD setae fine, less than ⅓ width and ½ length of D2, subtended by patches of darkened spinules. Distance from D2 to XD2 equal to that between D2 and SD setae. L2 and L3 about ½ length of L1; L3 on small elliptical pinaculum free of dorsal plate. Meso- and metathorax

with D1 pinacula fused over midline; MD1 twice as large as MSD setae on both segments. Mesothorax with D2 and SD setae on single pinaculum; metathorax with both D2 and L3 free of SD pinaculum. Claw with basal tooth ending about halfway to apex.

Abdomen. Integument with prominent vestiture of spinules over A1–A9 (Fig. 9). D1 on A1–A7(A8) arising from large, hemispherical, lightly melanized pinaculum; D2 on smaller, elliptical, slightly raised plate. Other setae subtended by small, darkly pigmented pinacula. SD and SV setae on separate pinacula. MV3 elongate on A1–A7 and grouped with SV setae on A3–A6; minute on A8 and A9. Distance from SD1 to L1 less than that between D1 and D2 on A9. Crochets in multiserial ellipse with five complete rows and one or two incomplete series.

Male Pupa
Figs. 12, 13

Cylindrical, 6–7 mm wide by 26–27 mm long, N = 2. Spination reduced; setae short, approximately equal to antennal width.

Head. Mandible with one seta. Cuticle over eye and mandible roughened. Labium short, ending before maxillae, broadest at base of palpus. Clypeolabral suture absent; labrum with one medial pair of setae and clypeus with two pairs laterad. Antenna extending to dorsolateral margin of mesotibia. Frons and vertex deeply furrowed. Vertex with small, paired cocoon cutters above base of antenna, each with two setae; and one seta to either side of ecdysial line.

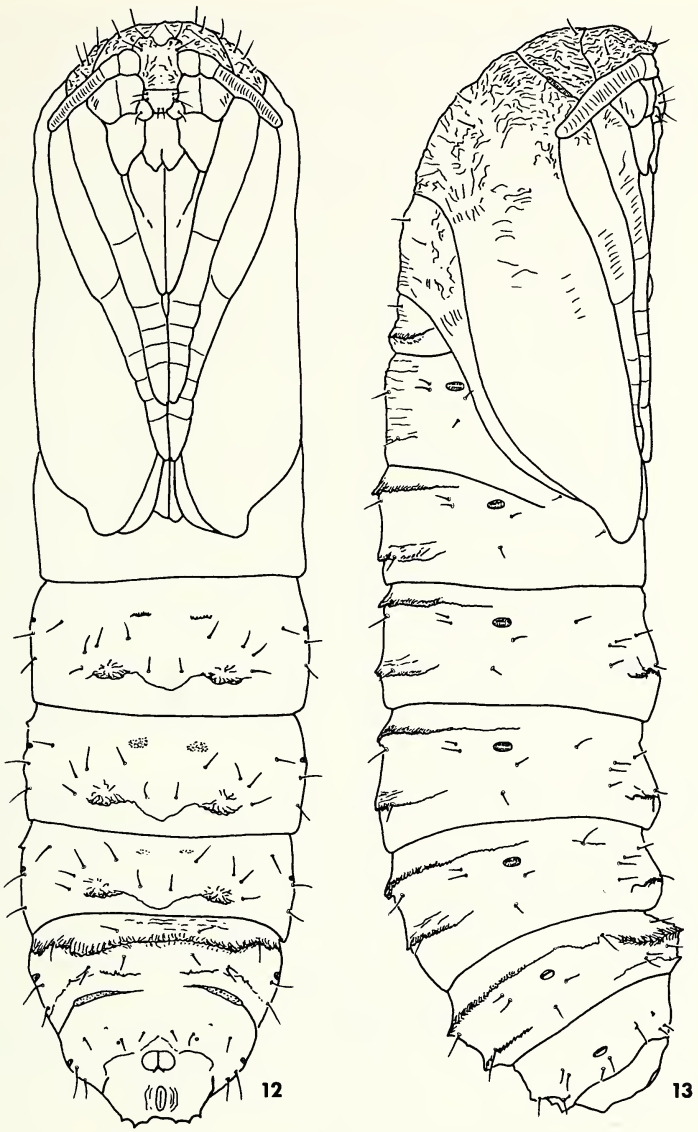
Thorax. Ecdysial line extending to A1. Prothorax with prominent deep furrows and six pairs of setae; prothoracic spiracle elongate, nearly twice antennal width. Meso- and metathorax roughened, each with two pairs of setae. Forewings produced at apex.

Abdomen. A1 with one pair of setae. A2 and A3 with seven setal pairs. Setae arranged as on larva on A3–A8, except with SV seta only on A8, although setal insertion may remain (1 of 2); A9 and A10 without setae; A1–A7 with transverse furrows over dorsum, these bounded cephalad and caudad by raised ridges of darkly pigmented teeth on A3–A7; anterior row extends below spiracle on A5 and A6, and completely encircles A7, where teeth form broad plate ventrad. Venter of A4–A6 with wavy, pigmented, fluted ridges over position of larval prolegs, these connected by thin pigmented ridge. Spiracles nonfunctional on A7 and A8. A9 with dark, Y-shaped genital slit with raised, darkened hemispherical area to either side; and low, broad, three-toothed horn dorsolaterad.

Female Pupa. 7 × 31 mm, N = 1. SV1 setal insertion absent on A8. A8 with short, dark genital slit that runs into furrows posteriorad which delimit A8 from A9 and A9 from A10.

DESCRIPTION OF MALE CALLING BEHAVIOR

Male calling behavior was studied at Mill Creek, Rennselaer County, where Ostrich Fern was the principal host. Males called for a very short period at evening. They did this by hanging from the tip of a fern frond (rarely using a taller plant growing amongst the ferns), obtaining a foothold with their first two pairs of legs (Figs. 1, 2). Suspended in this position, they next "fanned" their wings, thereby forcing air over



Figs. 12, 13. *Sthenopis auratus* pupa: 12. Ventral view; 13. Lateral view.

the metatibial scent brush (Fig. 1). Homologous metatibial scent brushes are found in all Nearctic *Sthenopis* species and in a number of related hepialid genera (Mallet, 1984; Wagner, 1985). Morphological details of the tibia and androconia have been studied in other ghost moths (Deegener, 1902; Deegener and Schaposchnikow, 1905; Wagner, 1985). Birch and Hefetz (1987) gave an overview of analogous androconial organs in male moths.

Attraction and courtship were not observed, although a single copulating pair was encountered by Howard Romack in Murray Hollow during the evening period of flight activity. The moths paired end to end, with one moth (male?) suspended only by its genitalia, a mating posture typical for other Hepialidae (Wagner, 1985). The duration of pairing was not noted.

Male calling behavior was observed 27 different times over the course of four years. The best viewing was at Mill Creek during a period from 25–30 June 1986. Sunset was at 21:04 EDST during this period of observation. The onset of flight and calling behavior was affected by ambient light intensities. For example, calling began earlier on overcast evenings. Similarly, a moth resting in a shaded recess began calling earlier than other males. Hence, our earliest record for calling, at 20.54 EDST, was of a moth sitting in a shaded recess on a day with an overcast skyline. Males typically began calling at the point at which human vision became insufficient and a flashlight was needed.

Many moths were observed to "fan" the wings for a few seconds or a minute or two, then became inactive although still suspended by the first two pairs of legs. Repeated observations suggested that this was due to the disturbance caused by the presence of the observer. Males occasionally flushed when probed, but quickly discontinued "fanning" if disturbed. Observations from twenty feet (versus 3 feet) indicated that males continuously fanned during the entire period of evening crepuscular activity (N = 9). Similar calling behaviors occurred in *Hepialus californicus* Boisduval and *H. hectoides* Boisduval. In both these species, the males called until a female was attracted or, in the absence of a female, for the 15–25 minute duration of the evening courtship and mating flight (Wagner, 1985). Mated females of *S. auratus* were active later into the evening. Such gravid females constituted the majority of light captures for this species.

The longest period of calling observed in a population was on 29 June 1987, when the first male was observed calling at 20:55 and one of several other males called until 21:21. Out of 27 males observed calling, the longest documented from initiation to completion was for 12 minutes and 35 seconds. Six or seven minutes was typical, although some of these moths may have been calling for a few minutes prior to when they were first discovered. On two occasions, a male was observed to fly to a new location and initiate a second display. Three times the male reached a new location but did not take up calling again. Several flushed males were unable to be tracked and were lost. All males observed calling for six minutes or more were finished calling for the night once they quit. They continued to hang from the fern tip (two were located still hanging by 01:00 hr), but changed locations before daybreak (N = 8). Frequently females were observed hovering over the fern patch, but none were observed approaching a calling male. On two occasions males were observed calling within four feet of another calling male. No aggression between males was observed. Both males and females were slow-flying and maintained a low altitude, barely above the tips of the fronds of fern. Moths located in the daylight rested suspended from a twig or leaf, not at the very tip of a leaf as when calling (N = 2).

DISCUSSION

The larva of *Sthenopis auratus* possesses several unique characters which serve to distinguish this species from other Nearctic hepialids: (1) L3 on a small, dark pinacu-

lum separate from the dorsal plate; (2) MD3 is elongate, nearly twice the size of the MSD setae on the mesothorax; (3) similarly, MV3 is elongate on A1, comparable in size to MV3 on A2–A7; (4) D1 on A1–A7 arises from a large, knob-like pinaculum; and (5) on all abdominal segments, both the SD and SV setae are located on separate pinacula. These characters outweigh any comparable list that could be compiled to separate other members of *Sthenopis* from Holarctic hepialids in the genera *Korscheltellus* Börner, *Phymatopus* Wallengren, and *Triodia* Hübner (Gerasimov, 1937; Aitkenhead and Baker, 1964).

Several species of hepialids are known to feed on ferns (Buckler, 1887; Barrett, 1895; Wagner, 1985; Wagner et al., in press). However, in no other species does the association with pteridophytes seem as pronounced as in *Sthenopis auratus,* which presently is known to feed only on three fern genera.

Larvae of another hepialid, *Korscheltellus gracilis* (Grote) have been collected from three of the four fern hosts of *S. auratus,* included are the two *Dryopteris* species and *Athyrium.* Larvae of the two moths are readily separable, however. The larvae of *S. auratus* appear bicolored, the nearly white ground color of the thoracic segments contrasting with the rusty-appearing abdominal segments. In *Korscheltellus* the ground color is uniformly whitish. In *S. auratus* the D1 setae arise from enlarged knobby pinacula on A1–A7; in *K. gracilis* the D1 pinacula are unmodified.

A female of *Pterocormus devinctor* Say was found emerging from a recently spun cocoon of *S. auratus* on 12 June 1987, at Murray Hollow. Elsewhere this ichneumonid has been reared from the pupae of *Sthenopis thule* (Winn 1912). The entomophagous fungus *Beauvaria bassiana* (Vuill.) was identified from a late instar larva found mummified within its tunnel during August.

ACKNOWLEDGMENTS

We thank Howard Romack for his assistance with the Murray Hollow population. We thank Douglas Wolfe of the Atmospheric Science Research Center whose cooperation facilitated field work on Whiteface Mountain in the Adirondacks. Brian Farrell gave permission to collect on his property near Indian Lake. Herb Holzer and Gerald Dievendorf assisted with field collections in the Albany area. The larval habitus, head capsule, hypopharynx, and mandible was illustrated by Patricia Eckel. Mary Ann Tenerio assisted with the larval preparation, scanning electron microscopy, and darkroom work. Henry Townes determined the ichneumonid. Charles Sheviak graciously introduced one of us (TLM) to the Mill Creek site. Eric Quinter shared (with TLM) in the discovery of the larva at Mill Creek. We thank Eric Quinter and Fred Rindge for their review. This work was supported, in part, by a Tilton Fellowship to DLW. Contribution number 581 of the New York State Science Service.

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Received July 5, 1988; accepted August 17, 1988.